

*QinetiQ*



# Networked Fibre Optic WIM Sensors

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# Presentation Structure

- Background
- Technology Description
- Field Trials
  - Trial 1 - Sensor selection
  - Trail 2 - Interrogation of multiplexed sensors
- Future Plans
- Summary & Conclusions

Section 1

# Background

## Section 1: Background

# Original Objectives

- Study into the feasibility of using fibre optic sensors to develop a traffic flow monitoring network
  - Develop networked fibre optic sensors capable of measuring traffic flow for Active Traffic Management (ATM)
  - Assess whether the technology has a WIM capability
  - Design an interrogation system capable of multiplexing sensors together and interrogating the sensors over a large distance
  - Evaluate sensor and interrogation system by performing a number of field trials



## Section 1: Background

# Earlier Fibre Optic Sensor Work

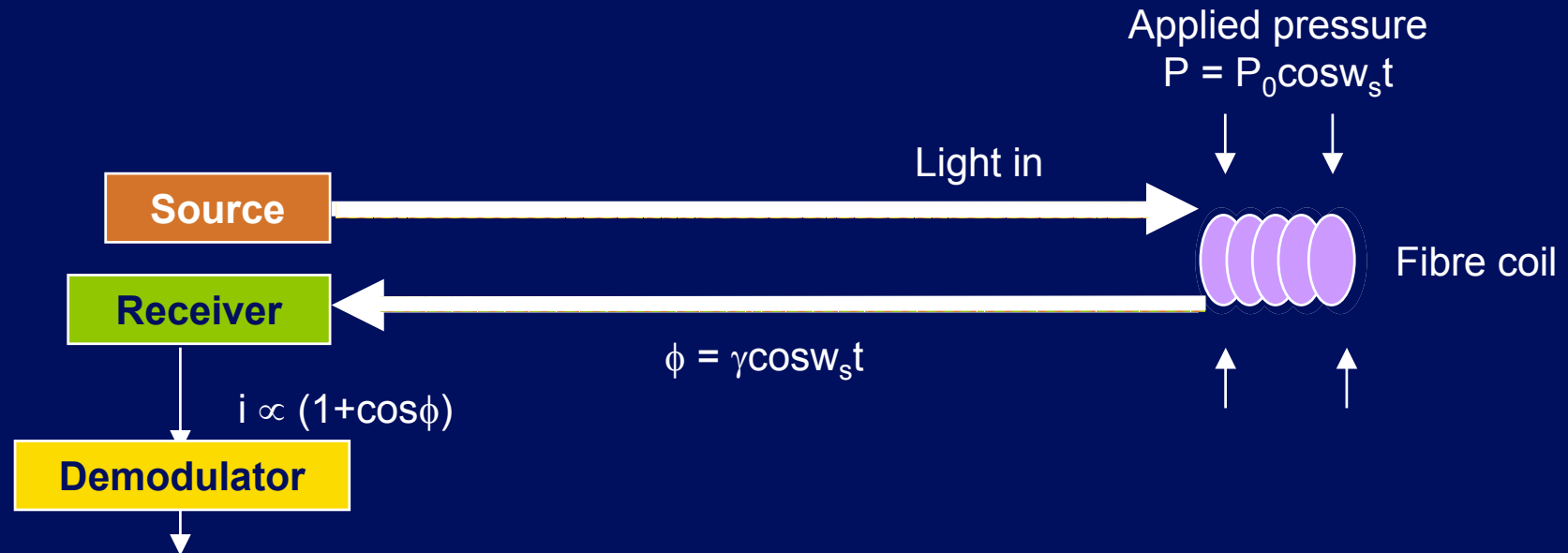
- Recent show of related papers
  - Caussignac, J.M., Larcher S. and Rougier, J.C. (1998), '*Weigh-in-Motion Using Optical Fibre Technology*', Conf. Proc., 2<sup>nd</sup> European Conference on Weigh-in-Motion of Road Vehicles, pp.429-434
  - Liu, G., and Chuang, S.L. (1998), '*Polarimetric optical fiber weight sensor*', Sensors and Actuators A, Vol.69, pp.143-147
  - Wierzba, P., Suopajärvi, P., Karioja, P., and Kopola, H. (1999), '*Optical fiber sensors for Weigh-in-Motion of road vehicles: state-of-the-art and future*', SPIE Vol.3746, Conf. Proc. OFS-13, P2-29, pp.522-525
  - Lee, H., Kim, K-S., Choi, N-Y., Yang, J., Cho, S-Y., Ryu, H. and Ha, Y. (2000), '*New Approach to Fiber Optic Weigh-in-Motion with Multiplexed Bragg Grating Sensors*', SPIE Vol.4185, Conf. Proc. OFS-14, P3-13, pp.732-735
- Commercial products
  - Sensor Line (MSI / Truvelo)

Section 2

# The technology

## Section 2: The technology

# Interferometric Fibre Optic Sensors



- Interferometric 'extended sensors'
  - Based upon the coiled fibre principles originally developed for fibre optic hydrophones, but extended in length to cover the width of a lane
  - Sensor allows high degrees of multiplexing and benefits from technical experience gained under military funded programmes

## Section 2: The technology

# The Benefits of Fibre Optic Sensing

- Sensing and signal transmission via common optical fibre
  - Available bandwidth allows multiplexing of many sensors ( $>100$ ) onto a single fibre
  - Remote interrogation over large distances ( $>50\text{km}$ )
- No electrical components used in sensing array
  - High reliability
  - EMI immunity
- Reduced cost
  - Use of components developed for the telecom industry
  - Savings made through multiplexing many sensors

Section 3

# Field trials

## Section 3: Field trials

# Field Trials

- Trial 1
  - To evaluate various different sensor designs
  - Characterise best sensor design by using various vehicle types
- Trial 2
  - To demonstrate how fibre optic sensors can be multiplexed together onto a single optical fibre
  - To demonstrate the interrogation of the sensors over a large distance (20km)

Section 3

# Field trials - Trial 1

## Section 3: Field trials

# Trial 1: Sensor Deployment

Soft grass verge

Conventional WIM System

Inductive Loop

Fibre Optic Sensors

1 2 3 4 5

3m long  
fibre  
optic  
sensor

3.2m  
long  
slot

Soft grass verge

3m

0.5m

0.5m

0.5m

0.5m

0.5m

Roadside  
Cabinet

Five different types of FO sensor were deployed

The third design gave the best response to passing vehicles

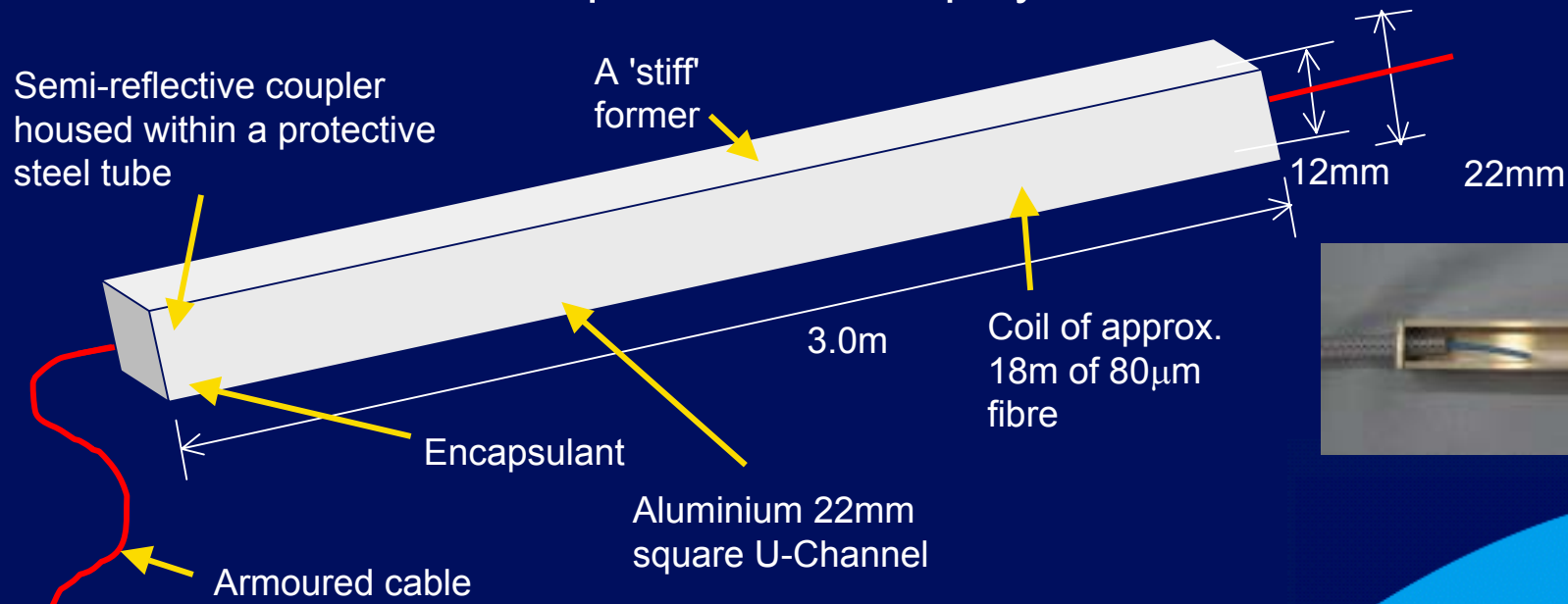


## Section 3: Field trials

# Trial 1: Sensor Design

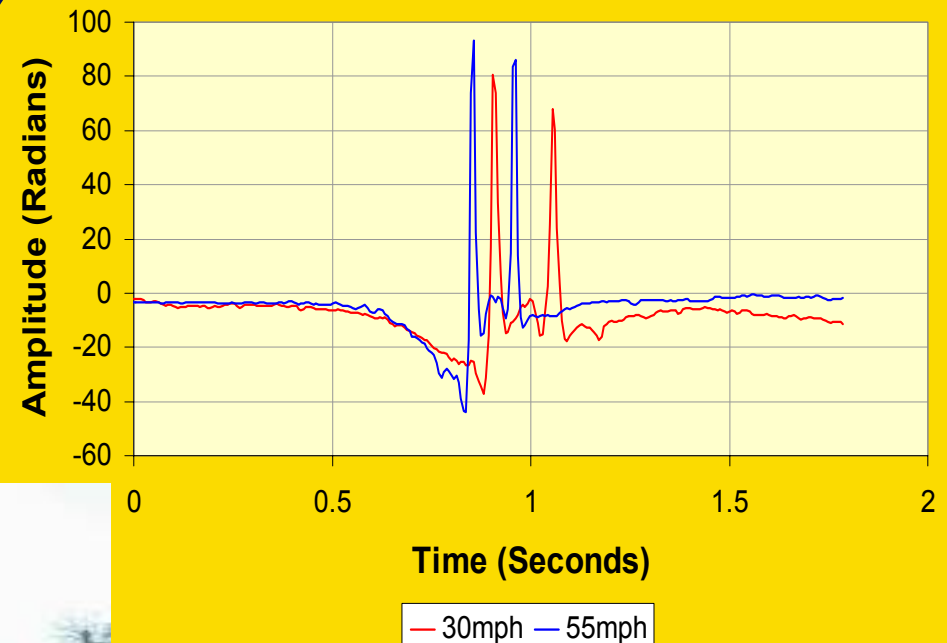
### Sensor 'Design 3' construction:

- Fibre coupler of a predefined split ratio with one mirrored port
- Second port connected to an 18m-fibre coil laid into a helical groove cut into the surface of a 2.6m long, 12mm diameter polyurethane bar
- Ends of the interconnecting cables, coupler and coil laid in a square aluminium channel, then potted in a soft polyurethane



## Section 3: Field trials

# Trial 1: Example Results (Car)

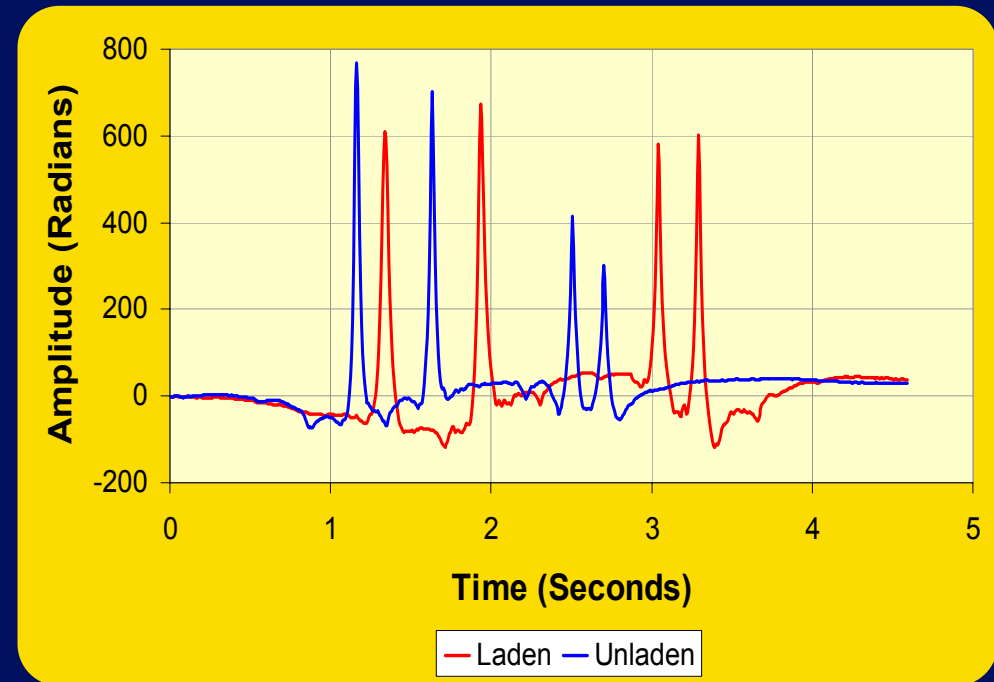


Response of a single fibre optic sensor to a passing car travelling at various speeds

## Section 3: Field trials

# Trial 1: Example Results (Lorry)

- Response of a single fibre optic sensor to a passing four axle articulated lorry, with and without a load.
- This clearly demonstrates the Weigh-in-Motion (WIM) capabilities of this type of sensor

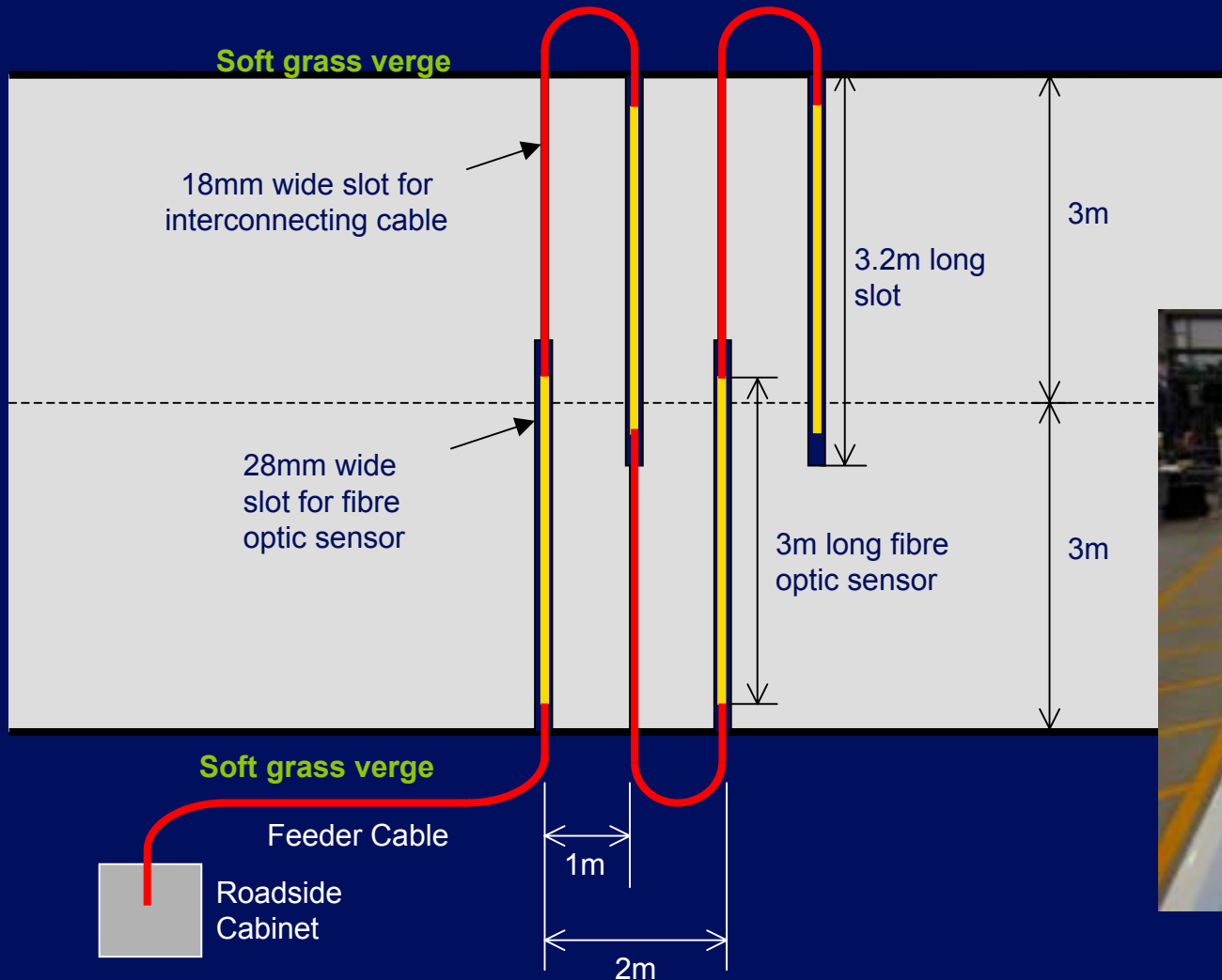


Section 3

# Field trials - Trial 2

## Section 3: Field trials

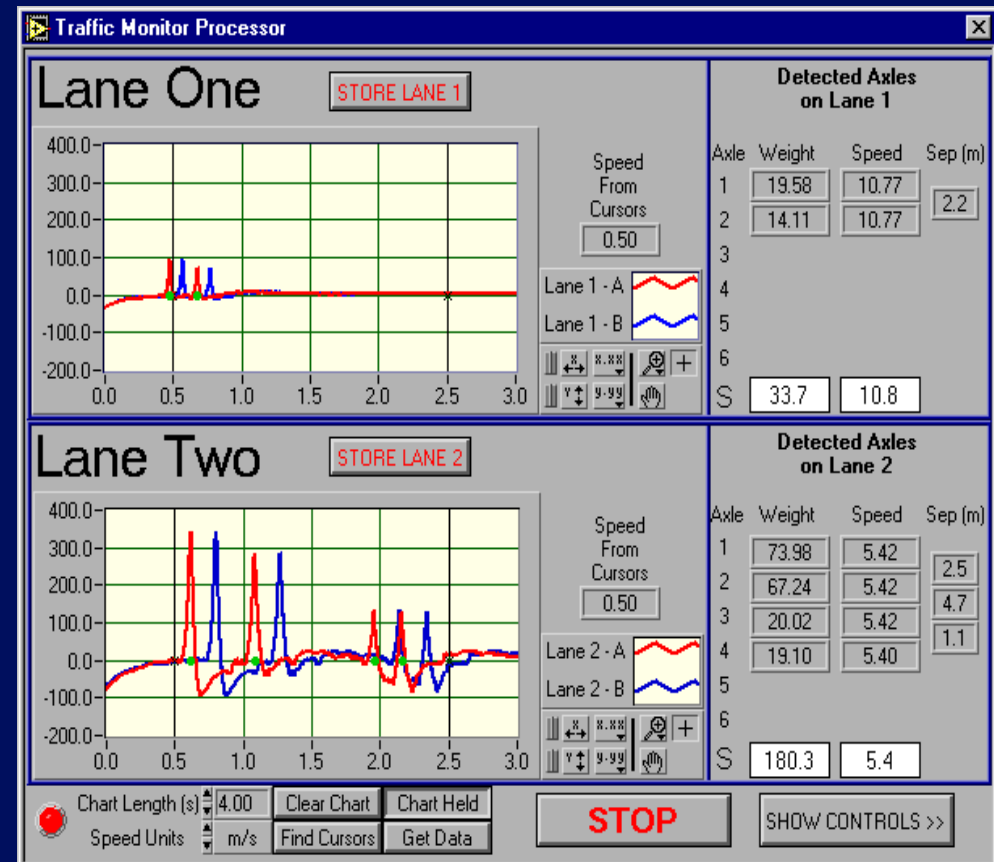
# Trial 2: Sensor Deployment



## Section 3: Field trials

# Trial 2: Four Channel System Display

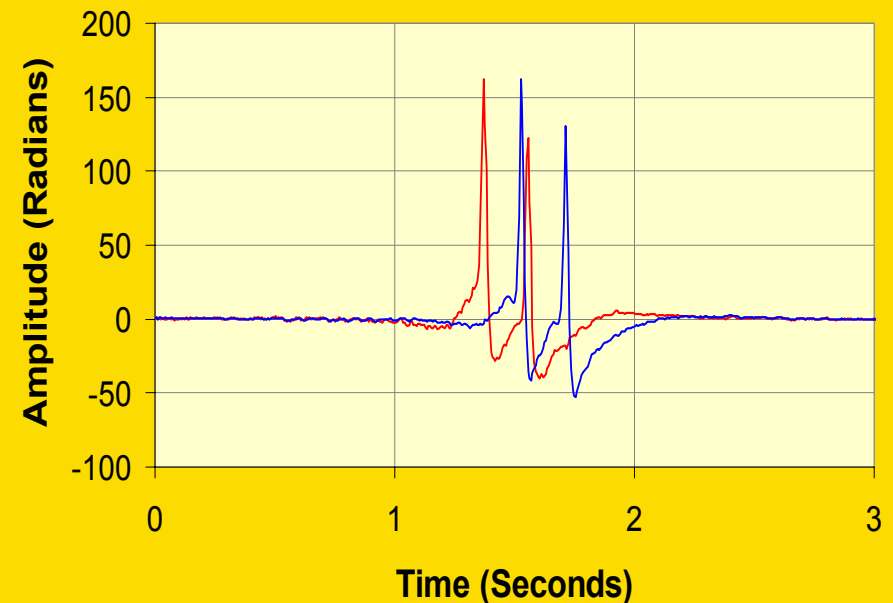
- LabView® display shows detected axles in both lanes (red and blue)
- Software calculates axle weight separation and speed, as well as overall vehicle weight and speed.
- Potential for 'generic' vehicle group classification
- Sensor interrogation via 20km fibre optic download demonstrated



## Section 3: Field trials

# Trail 2: Example Results (Car)

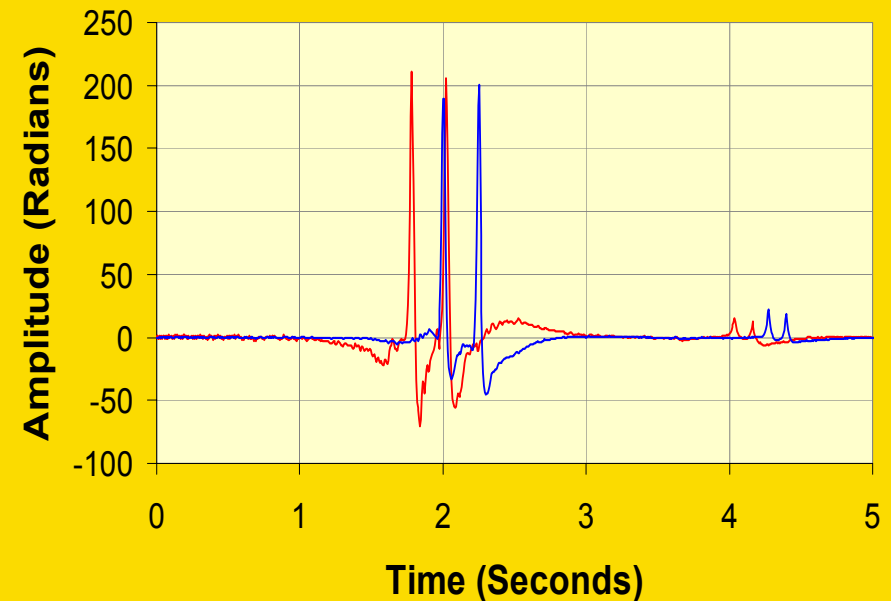
- Response of a pair of fibre optic sensors to a passing car travelling at constant speed
- This demonstrates that with two sensors it is possible to accurately measure vehicle speed by calculating the time difference between the two sets of pulses



## Section 3: Field trials

# Trail 2: Example Results (Car + Bicycle)

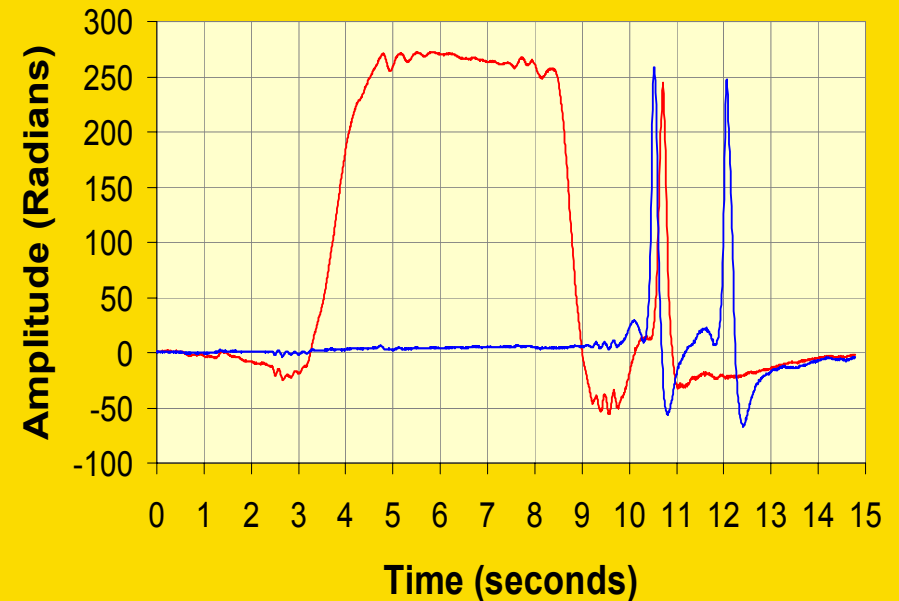
- Response of a pair of fibre optic sensors to a Land Rover followed by a passing bicycle
- This demonstrates that it is possible to detect various vehicle types with the same sensor



## Section 3: Field trials

# Trail 2: Example Results (Static)

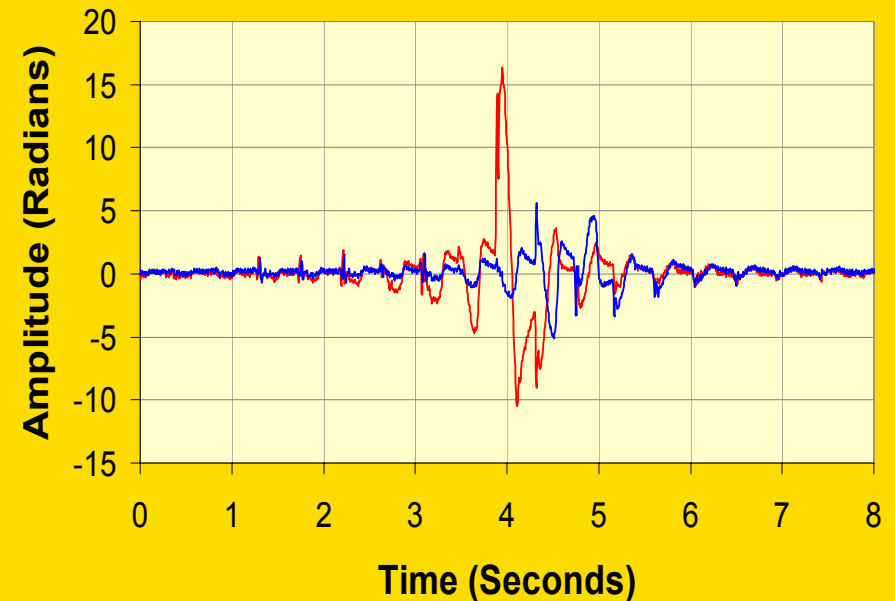
- Response of a pair of fibre optic sensors to a Land Rover whose front wheel came to rest over the first sensor before driving off.
- This demonstrates the the DC response of the fibre optic sensor



## Section 3: Field trials

# Trail 2: Example Results (Runner)

- Response of a pair of fibre optic sensors to a passing runner whose foot impacts close to the first sensor
- This demonstrates the high sensitivity of this type of sensor



Section 4

# Future plans

## Section 4: Future plans

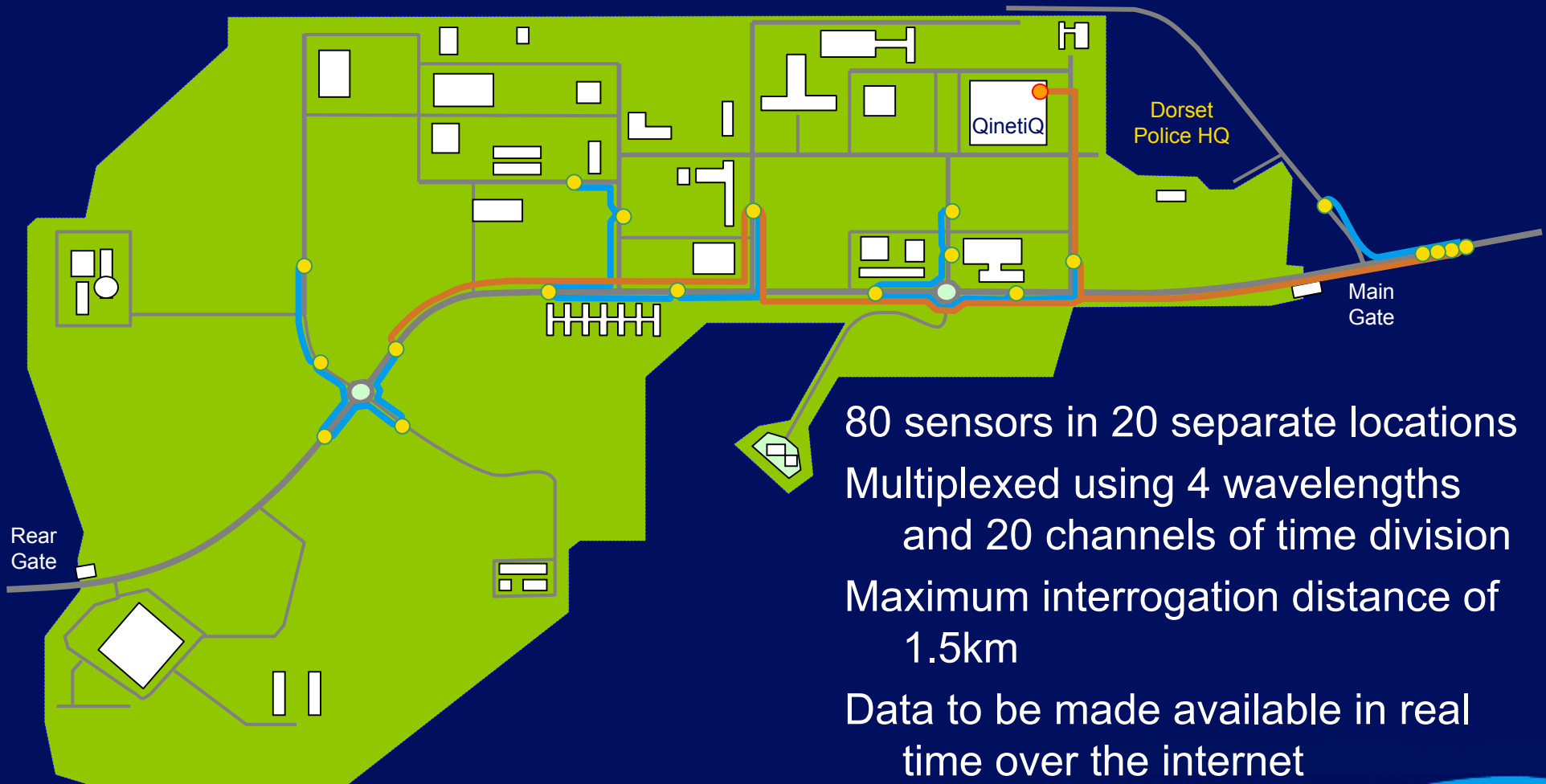
# Future Plans

- QinetiQ proposes a second phase to this work which will include:
  - The creation of a large network of sensors on the Winfrith Technology Centre site to evaluate alternative sensor designs and interrogation arrangements
  - The deployment on a motorway of several groups of multiplexed sensors to evaluate system under high volume / high speed traffic conditions



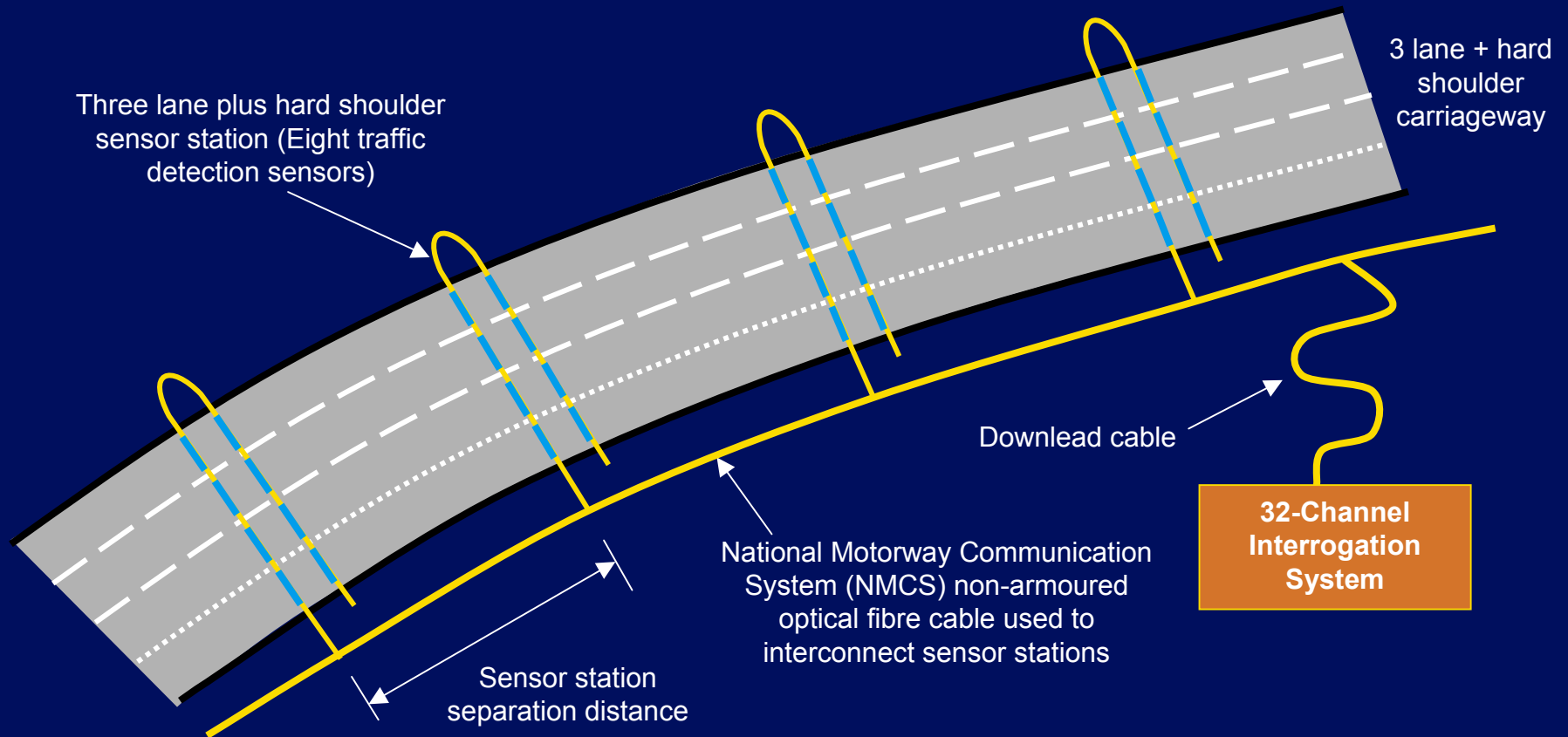
## Section 4: Future plans

# Winfrith Technology Centre Deployment



## Section 4: Future plans

# Three Lane Highway Deployment



## Section 4: Future Plans

# Improved Technology

- New sensor designs
  - Strip FO-WIM sensor. Flexible long flat sensor designed to eliminate 'bow' wave effects.
  - FO magnetic field sensor. Used to measure vehicle profile.
- Enhanced interrogation system
  - Multi-channel (128) real time digital demultiplexed / demodulator



## Section 1: Future plans

# Final Objectives

- To develop fibre optic sensing technology suitable for ATM and WIM application



- System will, where possible, use existing Highway fibre optic communication cables
- Provide additions fibre sensors to measure roadside environmental parameters such as temperature, moisture, and CO<sub>2</sub> emissions.
- Continue to exploit developments in telecommunication components to enhance the system

Section 5

# Summary and conclusions

## Section 5: Summary and conclusions

# Conclusions

- Successfully demonstrated the use of fibre optic sensors for the purpose of monitoring traffic flow
  - Four sensors multiplexed. By extending Time and Wavelength Division Multiplexing (TDM / WDM) hundreds should be possible.
  - Interrogation over a 20km download
- Potential to be used to determine flow in Active Traffic Management applications
- In addition we demonstrated the viability of performing Weigh-in-Motion measurements
  - WIM aspects require further calibration and evaluation